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A DEFINITION OF CAUSATION. II

PURSUANT to the empirical mode of investigating the causal relation which was explained and defended in the previous paper, we now take up the study of typical cases of causation. Following the outline already given, we consider first the types in the field of Mechanics. This field was divided into three parts: statics, dynamics, and transformation of kinetic into potential energy or the reverse. Under statics were found three principal laws or causal situations, first, that of the transmissibility of forces, second, that of the composition and resolution of forces, and third that of the moment of a force about a point as tending to produce rotation.

1. CASES OF MECHANICAL CAUSATION

Cases in Statics

"*Principle of the Transmissibility of Force.*—When a force acts on a particle, the force will produce the same effect if it be supposed applied at *any* point along a string connected with the particle, the string lying in the line of action of the force."[1] This principle is called an "axiom"; "it is one of the fundamental principles of rational statics, and in most treatises on the subject, it constitutes the basis of the investigation of the conditions of equilibrium" (p. 17). It holds only if the particle acted on remains the same as regards the relative positions of its parts, *i. e.,* if it is a rigid body. Stated in causal terms this means that a force acting at a certain point in a certain direction implies or determines its own existence at all points along that line. For if it were not conceived as already so existing, it could not be assumed at pleasure to be there. This elementary principle is by no means analytically self-evident; it is, in the Kantian sense, a synthetic judgment. Hence it needs explanation. In other words, it is desirable to see by virtue of what properties a force gets this implication. What is the constitution of the whole situation? Let the force act at A in the line AX and the direction from A to X. Then the principle tells us that the force acts at an adjacent point A'. It also tells us that it acts at a point A'' adjacent to A', and at another beyond and adjacent to A'', say A'''—and so on. Only by such a series of points, taken near at will to one another, can the generality of the position of the force along the line be guaranteed. Notice that the series is *started* by two points: the original point of application and the *direction* of the force—for a direction needs two points to determine it. But the universality of the positions of the force is due to the fact that all the positions are members of the series which is thus started.

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[1] G. M. Minchin, "A Treatise on Statics," 5th ed., 1896, page 16.

It is to be remembered that we are not here attempting to deduce the principle of transmissibility, but only to determine the conditions, observed and implied, under which it acts. As we shall meet series analogous to the above in later cases, further examination of it is at present deferred.

Composition of Forces

"If two forces be represented in magnitude, lines of action, and senses by two right lines OA and OB, their resultant is represented in magnitude, line of action, and sense by the diagonal, OC, of the parallelogram $OACB$ determined by these lines."[2]

In order to understand the meaning of this principle, we must ascertain what is meant by a force being "represented" by a right line of finite length. " . . . the magnitude of any force is estimated by the time-rate at which it generates momentum. Nevertheless in statics it is only the *tendency* which forces have to produce motion that is considered. . . . but the magnitude of each force is estimated none the less with reference to the amount of momentum which it would *actually* generate if it were completely unfettered by the action of other forces" (p. 9). The forces, then, which as causes combine to produce another force as effect must be understood as potential rather than actual motions; but their potential character does not prevent them from being actually present. They are in fact regarded as so present, and have different names, such as pressure, tension, attraction, repulsion. Thus, whatever philosophy may have to say of mere potentiality, science at least uses the notion to describe reality.

Next comes the analysis of the cause-effect relation here contained. The principle of composition is proved from the parallelogram of velocities. The latter is a matter of inspection. If a particle move in one second on a board from point A to point B, while the board is being moved so that the line AB passes without change of direction to the position *CD,* the body has possessed a velocity of *AB* per second and at the same time a velocity of *BD* per second; which is the same as one of *AD* per second. These two velocities are actually united in one body. Hence the forces, which are potential velocities, are also actually united, and without loss of identity on the part of either, into one new force. Superficially this appears to violate the law of contradiction. But it would not do so, even were we dealing with *real* motions; as shall be shown under dynamics. Were that not the case, however, it might still hold in statics: for the forces which combine are not actual motions, but potentialities. The law of contradiction as exemplified in space tells us that one line can not be another line, or one point another point; but it does not in the least imply that a *tendency* acting at one point can not be the same as two other *tendencies* acting at that same point. The law of contradiction tells us nothing at all about it; the whole matter is a question of fact. The concept of causation which is here employed by statics is, then, that of two terms in a certain relation (combination) uniquely determining a third, which is identical with the first two combined. The identity is thoroughgoing in space and time; yet in addition to it there is a difference, *viz.,* the left-hand member determines the right-hand, but not conversely.

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[2] Minchin, *op. cit.*, page 9.

Two potentialities may and do combine and produce a third potentiality identical with both yet with an added difference. It is possible to go further: two potentialities which are *entirely opposite in character* may combine to produce a resultant. That resultant is called equilibrium. Even if a body could not move in two opposite directions at once (though dynamics treats it as doing so) yet two opposite *tendencies* can coexist, neither being realized. Equilibrium is a real condition, and is identical with, uniquely determined by, such a coexistence of opposites.

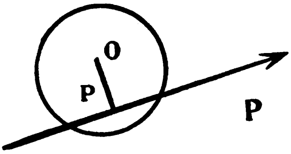
Of course, the concept of potentiality is out of fashion in philosophy just now—except with Thomists, who have always kept a respect for common sense—and must cope with many philosophical objections. It is not our present occupation to deal with them. We wish to know whether and how science *uses* potentiality; and if it finds itself compelled to use it in its causal determinations, that use must be respected, and potential factors must be given as good a title to objective validity as any other causal factors. Our general maxim is, to take what science gives us, and understand it and all that it implies, before we begin philosophical criticism.

Resolution of Forces

"Having proved the principle of the composition of forces, the principle of the resolution of force at once follows."[3] "The force *R* can be resolved in an infinite number of ways into two other forces" (p. 14). The causation here, however, must be interpreted with care. One force does not of itself give rise to sets of two forces: the pairs are not called resultants, but components. Statistics does not treat this aspect of the matter as a case of causation. Where the result may vary throughout an infinite field, the *Eindeutigkeit* peculiar to causation is lacking: it is rather chance than causation. If any determinate force comes out of the original one, there must be an additional qualification; *one* of the components must be fixed. That being done, the causal structure here is analogous to that of the principle of composition. The cause is twofold, the effect one. There is thoroughgoing identity between cause and effect. The force *R* being treated from the point of view of its component *A* is the component *B*. The subject of this sentence is the cause, the predicate the effect, because the former uniquely determines the latter.

The only reason why we do not like to say that a body tending to fall vertically toward the earth has also a real tendency to move at an angle of 45° with the earth's surface is because usually there is no obvious means of isolating that component. The scientific treatment does not hesitate to say so, when it is desirable in a given problem. The caution perhaps needs to be repeated that we must at present not criticize, but passively receive.

Force as Tending to Produce Rotation



"Let a force *P* . . . act on a rigid body in the plane of the paper and let an axis perpendicular to this plane pass through the body at any point, *O*. It is clear, then, that the effect of the force will be to turn the body round this axis (the axis being supposed to be fixed), and the rotatory effect will depend on two things—firstly, the magnitude of the force *P*, and, secondly, the perpendicular distance, *p*, of *P* from *O*. . . . The product $P \cdot p$ is called the moment of the force about the axis through *O*."[4]

This is a fundamental statical principle, which seems to be regarded as almost, if not quite, self-evident. The self-evidence does not concern us now; but the way in which it acts does. To simplify matters, let us consider a rigid horizontal bar capable of rotating about a point where it rests on a fulcrum. Suppose a pressure P exerted downward at the end of A. Its moment is $AO \cdot P$. Now how does it happen that this tends to make the bar rotate, *i. e.*, that it communicates an *upward* pressure to the other end, B? This is an elementary case of statical causation, and its constitution must be analyzed.

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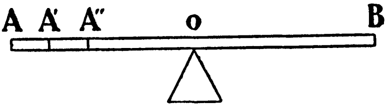
[3] *Op. cit.*, page 13.

[4] *Op. cit.*, page 106.



Let us designate the pressure exerted downward at A by x. The bar is treated as continuous and fairly rigid. This means that x is accompanied by a downward push at an adjacent point A'; if the end of the bar tends to descend, the parts of the bar in its neighborhood tend to go with it. Call the push at A', x'. It is also true that there is a downward push at a point A'' near A, such that it lies between A' and the fulcrum. Call this x''. Proceeding along the bar in this way until we reach the fulcrum, and taking the positions, A, A', A''. . . near at pleasure to one another, we find an endless series of pushes actuating the bar: $x', x'', x''', \ldots$. Abstracting for the moment, after the customary procedure of science, from the fact of the fulcrum and the magnitude of the pushes, we see that each member of this series differs from the next before it only in spatial position. We have, then, the series x, x', x'', x''', . . . where each term after x is similar to the preceding term in a very thoroughgoing fashion. That is, it is similar to it not only in general character as downward push, but in being followed by a term similar to itself. We may for the present purpose describe this series roughly thus: it seems to be determined by a first term x which is followed by the term x' which is in all save position exactly like x. For if this much is granted, x' will have the property which x has, of being followed by another term like itself, *viz.*, x'', which in turn, being like x', will be followed by another x''', and so on. A natural name for this kind of series is a *self-repeater;* it shall later be so designated.

This account neglects the fulcrum and its attendant circumstance, rotation of the bar. The rotation means that the downward push x' is less than x, and x'' is less than x, and so on. For the magnitude of the push is defined by the velocity it gives the body in unit time, and while the point A moves through a certain distance, the point A' moves through less than that distance. The members of the above series have not, then, that all but perfect likeness above asserted. They differ in magnitude; each being smaller than its predecessor in the ratio of their distances from the fulcrum. This does not effect their likeness in regard to that property of following which holds throughout the series; it simply adds to it by substituting "in all save position and magnitude" in the original description. When the distance from the fulcrum is zero, the downward push has zero magnitude. This does not mean that it is non-existent, for the situation here is one of equilibrium, a resultant of two opposite forces. The downward push is zero because it is really the resultant of a downward push on the fulcrum and the upward push of the fulcrum. When the distance from the fulcrum has a negative value, the magnitude of the downward push also has a negative value proportional to that distance. At B it has a negative value equal to that of A if $AO = -BO$; equal to n/m that of A if $AO = -n/m \cdot BO$.

Lest it seem that we have no right to dub a fact negative, we have to remember the meaning of negative in this connection. It is used in this field to mean of an opposite direction to what is called positive. Of the unreality which is by common cause associated with negation there is, of course, in this usage no trace. Accordingly we can accept as well the statement that an upward push at B added to an equal downward push at B when the arm OB is balanced with OA, constitutes equilibrium at B. It might be considered that two opposite motions of the same body at the same instant can not be: but two opposite simultaneous *tendencies* are, as we have seen, a very different matter, and there is nothing in the nature of space, time, or observed events to forbid the notion. So, at least, the scientific account of the matter thinks.

The whole situation has several distinguishable parts: the downward push of A, the bar joining A and B, the fulcrum, the proportion between push and distance, and the upward push of B. Now is only one of these the cause and one other the effect, or what? Philosophers have puzzled much over this problem of the difference between cause and condition; yet in this case the answer is, I think, a simple one. Let us see what part each element plays in the connection between A and B. The push at A is the starting-point. The series of pushes along the bar forms the connecting link between the starting-point and the end, the upward push of B. The fulcrum, which means the rotation and proportion between push and distance, simply modifies the character of each individual member of the series, without affecting their property of linking A and B. The situation may then be written: push at A—thread of linkage (modified by fulcrum)—push at B. Now the leading-through is done by the middle term, the thread of linkage. This leading is determined, if our description of the series was correct, by two terms, *viz.*, the push at A and the adjacent push at A' of such a character as to resemble A in all but place and amount. This description in fact really includes the influence of the fulcrum, in the phrase "in all but . . . amount." Accordingly, the last part, the push at B, is completely and uniquely determined by the first two terms of the series (including of course their relation). That alone suffices to guarantee the existence and the character of the push at B.

Since, then, there are, from the point of view of unique determination or explanation, just *two* parts of this whole complex—the determining one being two related terms, the determined one being any term later in the series—there is nothing to do but to consider the former as the cause and the latter the effect. There is here no distinction between cause and condition, unless one of the two related terms be arbitrarily designated cause and the other condition. But this has no ground, since both appear necessary to start the series.

This analysis of statical situations might be considered itself somewhat arbitrary. We have picked out certain elements—mainly spatial ones—and neglected others such as color, kind of substance, time of day, etc. Mach seems to regard this as prejudicial to the objectivity of science.[5] It needs but to recall our present purpose. If science has found its causal explanations by neglecting certain points, we have to accept that fact. It has been able to succeed in its quest by so doing; hence we must conclude that the facts neglected make no essential difference.

All other cases of statical causation, so far as I know, reduce to the above cases and combinations of them. By the principle of composition, such combinations contain in the very fact of being combinations, no new causal principle. They are themselves cases of composition (or resolution). Non-coplanar forces are treated by the aid of the above principles alone. Hydrostatics and the statics of gases, again, involve no new types; ready mobility being the main differentia of these branches. Of course coefficients of friction, resistance of media, density, elasticity, enter into the statical equations: but this is once more a compounding of different causal types, and these latter shall soon be examined on their own merits.

Types of Causation Found in Dynamics

The fundamental types here seem to be the composition and resolution of velocities and accelerations, and the laws of motion. Under the latter belong cases of a body at rest or in uniform motion, of a body acted upon by external forces such as gravitation, and of bodies under impact or collision with other bodies.

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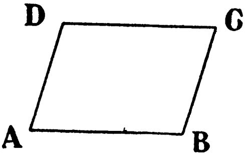
[5] "Mechanics," page 9.

Composition and Resolution

The way in which the parallelogram of velocities is constituted has been shown under statics. That of accelerations is completely analogous. Now force in dynamics is represented by the acceleration given to a certain mass. Therefore, forces are compounded and resolved in dynamics just as in statics. In fact, the only reason for discussing this type of case here is that it seemed, according to the treatment above, that only potentialities or tendencies could be compounded without loss or destruction. Thus, if a particle have



acceleration *AB* and also at the same time acceleration *AD,* then in a unit of time it moves through a distance and in a direction which gives it acceleration *AC;* but thereby it reaches point *C,* and not *B* nor *D*. Hence the forces represented by accelerations *AD* and *AB* seem not to have been actually realized.

It all depends upon what we mean by a force. Two ways of interpreting it are possible; and on one of these ways the composition and resolution become fictions, on the other truth. A force may be through and through particular, defined by a particular point of application, a particular magnitude, a particular direction; or it may have something of the universal in its nature, which permits it to be transferred or transmitted from one place to another while remaining the same force. These two interpretations are *a priori* possible; but science in its empirical procedure has adopted the second. It speaks of forces being transmitted, and treats them as if they were transmitted; just as it speaks of velocity being transferred, momentum imparted, etc. Indeed it is not science that is nominalistic, but certain philosophic views *about* science. Suppose now we take this universalist interpretation of a force: then a force may itself be translated through space while remaining just itself. The force which imparts acceleration *AC* *is* that force which gave acceleration *AD,* its point of application being translated with acceleration *AB*. It has shifted its point of application, but has retained the same direction and magnitude. It has moved the particle from *A* in the direction *AD* by the amount *AD;* for the point *D* is actually removed by that amount and in that direction from *A*. If it be objected that in dynamics a force is not an entity in itself, but simply the acceleration of a mass, the same argument holds; for the basis of it is that accelerations may be compounded. The only ground for rejecting real composition seems to be that a line, considered by itself, *is not* two other lines. But a line, considered in relation to other lines or points, may have a property that it has not when considered alone, *viz.*, the property of leading in different directions according to the lines with reference to which it is considered.

Accordingly the law of composition implies a true identity between the forces (accelerations, velocities) which combine and the resultant force. The structure of the causal relation is the same as in the corresponding case of statics.

A special case is that of two equal and opposite forces. This seems at first to be a *reductio ad absurdum* of the principle, inasmuch as the resultant is zero. How can zero be identical *in dynamics* with two real forces (accelerations, velocities)? Now in statics this was, as we have seen, perfectly possible; for *there* we had only potentialities, tendencies, not actual motion. But in dynamics, where there is no motion there is force. Hence we either pass in this case into statics—kinetic energy becoming potential, as in a body propelled upward against gravitation—or into some other form of energy than either, as when impact of inelastic bodies gives rise to heat. These cases shall be later examined; but even now it is evident that the effect of two opposite forces never is *merely* zero acceleration.

The resolution of forces is analogous to the same in statics.

It may here be asked, why do we not include a principle corresponding to that of rotation in statics? For perfect symmetry it ought to be done. But the structure of the causal situation is obviously the same as that of the statical principle; so we pass it entirely over.

Inertia and Rectilinear Motion

There has been a great deal of discussion as to the proper formulation of Newton's laws; but it is our good fortune at present to be able to avoid it. The nature of our problem enables us to take the statement of any standard text-book, treating it as *very nearly* what happens in the actual world. The first law says:

"A body continues in its state of rest, or of straight uniform motion, except in so far as it is compelled to alter that state by impressed force."[6]

The direct implication is that a body, being at one moment in a state of rest will, if the forces acting on it remain the same, be in the same state at a later moment; and similarly if it be in straight uniform motion for one period of time it will, if other conditions acting on it remain, etc., have the same straight uniform motion at a later period. Its earlier state determines its later state; the later state is accounted for by the law which connects it with that earlier state. It might conceivably have been otherwise. Bodies might begin to move of themselves, or to stop of themselves; this was indeed a primitive belief. But they do not. Why? It is not self-evident, or an analytic judgment, though such a view has been defended; for time goes on and other things change while a certain body remains (nearly) at rest in a given system. But even if it were self-evident, it is a type of the behavior of bodies in which the earlier state is by science believed to determine the later. That is, it is a causal situation.

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[6] Williamson and Tarleton, "Dynamics," London, 1889, page 25.

If a body is at rest in a given system (or in the universe, as defenders of absolute motion would say) for a given period of short duration, then at a slightly later period, with the same duration, it is at rest, and also at another similar period, later by the same difference than the second. If difficulties are here raised by the terms "same duration" and "same difference" the reply is that we mean by them just what they are used in dynamics and physics to mean. This series we have begun continues indefinitely in time. Denote the body throughout the first period by x, throughout the second by x', and so on. Then the series is defined by the following: a term x is followed by another x' which resembles it in all save position, and is therefore followed by a similar term x''. The series thus begun will go on indefinitely, just as, to use Royce's illustration, a map of England in England implies a map within itself, and so on. This is moreover an *adequate* description of the series which defines this case of inertia. For it holds, however small the successive periods become, and however near together, and it holds through the whole time. The causal structure here is analogous to that of transmission of pressure along a rigid bar rotating about a fulcrum, in statics.

If a body is in uniform motion in a straight line, the terms of the series become equal displacements in equal times; otherwise the series is the same. However short the motion is, it has been repeating itself indefinitely often.

The question of relativity of motion, time, space is indifferent to this analysis. If a body's motion is uniform in a given system then, other conditions being unaltered, it continues uniform in that system. The fact that a line which is straight in one perspective is sometimes not so in another is also irrelevant, provided the same perspective is maintained. A uniform circular motion, or spiral motion, continues uniform and of the same kind (circular, spiral) so long as the conditions are unchanged; being a compound motion, the resultant of two or more which are uniform. A uniform acceleration, which is the combination of an original motion with a constant force (as in gravitation) continues uniform while the conditions are unchanged (*i. e.,* distance from the center of mass of the earth). We need not discuss the question, whether all forces *must* be defined by straight lines. This is claimed by some,[7] but its necessity lies beyond the scope of our problem. Dynamics and physics *do* so define it and thereby succeed in explaining their phenomena; here we only take passively what these sciences give us.

A certain *reductio ad absurdum* here appears. The endlessly repeating series must by its very definition go on forever; but rest and motion of the bodies we know, do not go on forever. But, as the treatment of impact and of some later types will show, *momentum is* always conserved; that is, the same amount of motion of the same mass. When a resting body is moved, the rest becomes force of inertia or tendency to resist motion; a real and measurable condition, though only a potentiality. When a moving body is stopped or turned in another direction, the motion in the original direction continues, either as element of a composition of motions, or as transferred without loss to some other body, or as internal motion in the shape of heat.

As to the concept of mass here used, it is not necessary to assume that it represents quantity of matter. It may be defined, as Mach and others claim, by means of acceleration produced in other bodies. The conservation of mass is an empirical result, and is unaltered by conceptual analysis. It is *found* that the total power of producing accelerations in a given body remains unaltered by change of position or spatial configuration. Perhaps, as Natorp, Wundt, Meyerson, and others suggest, this is *a priori* necessary, because space by its very definition would be incapable of affecting mass. But we have here no concern with attempts to prove any causal process *a priori* necessary. In the sequel the question of necessity must be discussed; at present our task is only to understand what causation is.

The Case of a Body Acted Upon by External Forces and Consequently Changing Its Motion (or Rest).

If the force acting on the body is uniform (or nearly so) and continues acting indefinitely, as is the case in gravitation, the velocity given the body in a short period of time is simply added to that rate of motion it had just before. The series of short successive periods is then composed of members each of which has a constant numerical ratio to the one before it; x is followed by x' which is just so much greater than x, and x' resembles x otherwise in all but its position in the series; *i. e.*, x' is followed by x'' which again is greater by the same ratio than x' — and so on. The type of causation is the same as before. Here the force of gravitation is spoken of as the cause; but little, if anything, is known of the way in which this force arises and influences the motion of bodies. Hence we must confine our attention to the way in which the motion of bodies goes on under the influence of this force; regarding the earlier displacement, velocity, acceleration, as, under that influence, determining the later displacement, etc.

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[7] E. Meyerson, "Identité et Réalité," page 76.

With an *impulsive* force, whose action ceases almost instantaneously, the series of conditions *after* its action has ceased is one of uniform motion. The *communication* of the impulse may occur in any manner, and consequently will come under one of the types of causation later discussed. One of these is taken up in the next section.

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VALUE AND EXISTENCE IN ART AND IN RELIGION[1]

BETWEEN the profound and the commonplace the difference is obscurity of statement: a profundity is a commonplace formulated in strange or otherwise unintelligible terms. This must be my excuse for beginning with the trite remark that the world we live in is not one which was made for us, but one in which we happened. I say this with all due deference to idealists and other pious persons who believe that the trouble is only with us, and not at all with the world, and I wish I could agree with them. I can't, because for one reason, if the world were actually as they think it, they could not think it as they do. Indeed, they could not think. For thinking arises always as reaction to discomfort, to pain, to uncertainty, to problems, and these could not exist in a world which was made for us. It is notable that those who believe it to be such devote most of their thinking to explaining the discrepancy between the world's seeming and the world's being. Their chief business, after proving that the world is all good, is solving "the problem of evil." Now if really there were no evil, this evil consequence could not have ensued: existence would have been a beatitude and not an adjustment, and thinking would have been self-absorbed contemplation, blissful intuition, not painful learning by the method of trial and error.

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[1] Read at the annual meeting of the American Philosophical Association, 1913.